MULTIMODE SIMULATIONS OF FREE ELECTRON LASERS

Joseph A. Blau-DoD Civilian
B.S., University of California, Santa Barbara, 1987
M.S., University of California, San Diego, 1989
Doctor of Philosophy in Physics-March 2002
Advisor: William B. Colson, Department of Physics

The results of theoretical research on Free Electron Lasers (FELs) are presented. Basic FEL physics is reviewed, using a previously developed classical theory. Numerical simulations based on this theory are described, and numerous examples show how they have been used to increase understanding of existing FELs and to help plan new experiments. Single-mode simulations that follow the evolution of a single-frequency plane wave provide insight into important physical effects in FELs. Results show how these simulations are used to evaluate new FEL designs such as inverse-tapered and step-tapered undulators. Longitudinal multimode simulations model plane waves using finite-length electron and optical pulses. These simulations are used to study coherence evolution in various FEL designs, and to explain effects such as limit-cycle behavior. Transverse multimode simulations that allow for the finite transverse dimensions of the optical wavefronts include the effects of optical mode distortion. These simulations are currently being used to design short Rayleigh length optical cavities that are less sensitive to mirror damage. Four-dimensional simulations are also described, which follow the optical wavefront in x, y, z, and t, including the effects of multiple longitudinal and transverse modes. These simulations are computationally intensive, but may play an important role in the design of future high-power FELs.

KEYWORDS: Free Electron Lasers, Numerical Simulations, Directed Energy